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I, JULIE BILLINGSLEY, TEAM LEADER EXAMINATION SUPPORT AND SALES hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. 2003900295 for a patent by ONESTEEL REINFORCING PTY LTD as filed on 23 January 2003.



WITNESS my hand this
Fifth day of February 2004

A handwritten signature in cursive script, reading "J. Billingsley".

JULIE BILLINGSLEY
TEAM LEADER EXAMINATION
SUPPORT AND SALES

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AUSTRALIA
Patents Act 1990

PROVISIONAL SPECIFICATION

Applicant(s):

ONESTEEL REINFORCING PTY LTD

UNIVERSITY OF WESTERN SYDNEY

Invention Title:

A STRUCTURAL FORMWORK MEMBER

The invention is described in the following statement:

STRUCTURAL DECKING SYSTEM

Technical Field

5 The present invention relates to structural decking systems and to composite slabs that include the systems.

10 The present invention also relates to a method of manufacturing structural decking systems.

15 The present invention relates particularly to structural decking systems for constructing composite slabs.

20 A major, although not the only, end use application of such structural decking systems is in the construction of composite slabs that form floors in buildings (which term includes car parks).

25 Another, although not the only other, end use application of such structural decking systems is in the construction of composite slabs that form vertical wall panels.

Background Art

(a) Conventional composite slab construction

30 Structural steel decking can serve a dual function when used in the construction of composite steel/concrete floor slabs and beams. The decking can act as structural formwork by supporting building materials and personnel before concrete hardens. In addition, after
35 reinforcing steel (bars and/or mesh) has been laid, and concrete has been poured on top of the decking, and the concrete has reached sufficient compressive strength, the

decking can act as main reinforcement by interacting with the concrete. When the decking acts as a main reinforcement it will continue to do for the remainder of the life of the building.

5

All of the types of steel decking described in this section interact with the hardened concrete to take advantage of composite action.

10

The cellular panel described in Australian patent application 12620/70 in the name of H.L. Burn et al is a one-way load-carrying panel that falls outside this description.

15

(b) Existing steel decking profiles

20

Conventional structural steel decking is roll-formed from flat steel strip into long panels of uniform cross-section. Decks are principally distinguished by differences in their cross-sectional shape or profile. The profiles used in the world today are very varied, e.g. trapezoidal decks with "open ribs" (see Fig. 1(a)) versus decks with "closed ribs" (see Fig. 1(b)), but they all have one factor in common: the nominal thickness of the sheeting is constant around the profile perimeter.

25

Also, roll-forming machines are only designed to roll steel sheeting up to a certain maximum thickness, e.g. 1.2-1.6 mm. This significantly restricts the maximum flexural stiffness and ultimate strength of a deck with a set geometry. This in turn can severely impact on the minimum overall depth of the steel decking that can be used to achieve a certain span, which itself can significantly affect the minimum overall depth of the composite slab.

35

Conventional roll-forming machines are only used

to manufacture one profile of steel decking. The nominal dimensions of the geometric features that define the profile, e.g. the overall depth, cannot be significantly varied.

5

Therefore, if a greater spanning or load-carrying capability is required and the profile must be changed, then new roll-forming sets must be built.

10

Therefore, with demand growing in the world today for decking to be used in a variety of applications, major decking manufacturers are beginning to produce a suite of decks from flat steel strip, with each deck requiring different roll-forming sets.

15

The suite of decks includes some very deep decks (greater than 200 mm) that are used in the construction of composite slabs having a thin coverage (typically, 50 mm) of concrete and exhibit one-way action.

20

Flat steel strip used to roll form any given deck is one steel grade. Therefore, the steel in all of the parts of a roll-formed deck (flanges and webs) has the same yield stress.

25

The coating on flat steel strip can be varied to some degree between the top and bottom surfaces. For example, it can be galvanised on both surfaces but pre-painted on the side that will form the soffit exposed to the air. Alternatively, the steel can be uncoated on both sides, which is done in benign environments to reduce the cost.

30

Some decking manufacturers modify the decks they produce once the decks have been roll-formed. This is done to improve their functionality or structural performance. Important aspects of structural performance are flexural

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stiffness and ultimate strength. Flexural stiffness affects the magnitude of vertical deflections, in particular under the weight of wet concrete, which often control in design. The moment capacity and shear capacity of critical regions affects ultimate strength, which can also control in design.

Two types of modified decks are discussed below.

- 10 (i) "Cellular" decks that are made by welding a flat sheet of steel across the entire base of each decking panel (see Fig. 1(c)).

15 This arrangement creates closed cells for the passage of sensitive building services, in particular electrical cabling for computers, thus giving rise to so-called "electrified floors".

20 Attaching the flat sheets to the decking panel also increases the load-carrying capacity and flexural stiffness of the original deck, provided the connection between the sheet and the deck is sufficiently strong. Therefore, this functional improvement can also improve the structural performance of the deck when it acts as
25 formwork.

Importantly, for example as is disclosed in Canadian patent 704842 in the name of H.H. Robertson Company, the decking element fixed to the top of the flat
30 base sheet may be incomplete, with the base sheet incorporating side lap joints. This also led the inventors of the patent to adopt the unusual option of welding the W decking without the lap joints upside-down to the underside of the same decking with lap joints, thus
35 forming a closed multi-cell box deck. Similar decks are shown in Canadian patent 692135 in the name of Inland Steel Products Company's.

Japanese patent 11-192613 in the name of NKK Corporation shows a form of cellular deck which includes a series of openings in the webs of the trapezoidal ribs to accommodate transverse reinforcing bars. It is not clear from the patent the way the cellular deck is manufactured. In any case, the trapezoidal rib of the panel is formed as one part and would therefore be of uniform thickness like conventional decking. It could be that these trapezoidal ribs (which could also be referred to as inverted troughs) are individually welded to a flat plate to form an inverted form of the cellular panel described in Burn's Australian patent application 12620/70. The transverse reinforcing bars appear to clip into the holes in the web sides, and most likely act as shear keys in the final composite slab once the concrete has hardened, noting that the concrete would fill the decking ribs and encapsulate the bars. Another arrangement shown in the Japanese patent application appears to comprise transverse reinforcing bars welded to the tops of the trapezoidal ribs, presumably again to promote composite action between the decking and the concrete.

(ii) The structural performance of a closed-rib decking produced in Australia (Stramit's Condeck HP) has recently been improved by screwing a continuous rib to the side of the lap joint when it acts as formwork (see Fig. 1(d)).

This attachment is located on the top face of the decking and is cast in the concrete and can potentially increase or decrease the longitudinal slip resistance of the plain deck, depending upon its design and the strength of its connection to the rib.

However, in accordance with the manufacturer's recommendations, the attachment is only connected to the

steel decking by three small screws placed through the rib sides (one at the end support, one at mid-span, and one at the accessory end within the internal span), and by two small screws or shot-fired pins through the base of the accessory and into the steel beams at the ends of the span being strengthened. Therefore, interaction between the sheeting and the accessory is very limited. The manufacturer discounts any improvement to the flexural stiffness of the steel decking on account of the accessory. The moment capacities of peak moment regions are assumed to increase, but the increases claimed again only reflect a low level of longitudinal shear connection between the decking and the accessory. Another major disadvantage with this invention is that the accessory must be fitted when the sheeting is in its final position in the building. The manufacturer discounts any effect that the accessory might have on the longitudinal slip resistance of the deck, which could be unconservative.

The description of the modified decks in items (i) and (ii) above is not to be taken as an admission of the common general knowledge in Australia.

Disclosure of Invention

The present invention is an alternative structural decking system to the above-described systems.

According to the present invention there is provided a main decking panel for a structural decking system that includes a plurality of the main decking panels, with the main decking panel including:

(a) a base component that includes a central pan and lap joints on each side of the pan to enable adjacent main decking panels to be positioned side by side in overlapping relationship; and

(b) a strengthening component in the form of an inverted channel member secured to the base component, with the channel member including two opposed side walls
5 formed from web components and a top formed from a chord component, and with the web and top chord components being manufactured as separate components and thereafter assembled together to form the channel member.

10 According to the present invention there is also provided a structural decking system formed from a plurality of the above described main decking panel positioned side by side with the lap joints in overlapping
relationship.

15 Preferably the structural decking system includes one or more than one infill decking panel that is positioned between two main decking panels, with the infill decking panel including lap joints on each side of
20 the pan that are in overlapping relationship with the lap joints of adjacent main decking panels.

According to the present invention there is also provided a composite slab that includes the above
25 described structural decking system and a layer of hardened concrete on the structural decking system.

Best Modes of Carrying Out the Invention

30 The main features of the preferred embodiments of the main decking panel and the structural decking system of the present invention are described below with reference to Figures 2 to 11.

35 It is noted that the main decking panels are described as "hybrid" decking panels in the Figures.

The structural decking system of the present invention is based on modules in the form of main decking panels and infill decking panels.

5 As can best be seen in Figs. 2, 3 and 4 a preferred embodiments of the main decking panel each include:

(a) a base component that includes a central pan and lap joints on each side of the pan to enable adjacent main decking panels to be positioned side by side in overlapping relationship; and

(b) a strengthening component in the form of an inverted channel member that is secured to the base component, with the channel member including two opposed sides formed from web components and a top formed from a chord component, and with the web and top chord components being manufactured as separate components and thereafter assembled together to form the channel member.

Each preferred embodiment of the infill decking panel shown in the figures preferably includes a central pan and lap joints on each side of the pan that are formed to allow the infill decking panel to be positioned in overlapping relationship with the lap joints of adjacent main decking panels.

Two specific embodiments of the infill decking panel are shown in Fig. 2(d). The lower embodiment has a flat pan and the upper embodiment has a trapezoidal profile.

Preferably the main decking and infill decking panels are narrow single units (see Figs 2, 3 and 4). The preference for narrow modules is to keep the weight per unit length down and allow the panels to be used in long

lengths and lifted individually and easily handled on site by workers.

Being the main spanning elements, the main
5 decking panels can be used by themselves (see Figs. 3(a) and 4(a)).

Alternatively, infill decking panels can be
fitted between the main decking panels to improve economy
10 (see Figs 3(b) and 4(b)), since they are less costly to manufacture than the main decking panels.

Using infill panels makes it possible to
introduce voids between adjacent main decking panels or to
15 accommodate longitudinal prestressing cables or reinforcing bars placed low in a composite slab.

The main decking panels are preferably placed in position first to support the infill panels, which only
20 span in the transverse direction perpendicular to the main span.

The main decking panels are preferably assembled from purpose-built steel components (see Fig. 2).

25 The major dimensions (e.g. thickness, width or height) and the mechanical properties of the steel components can be varied in production to provide main decking panel designs that are more economical than the
30 known decking systems described above and which can satisfy a wide range of demanding design requirements including achieving very long un-propped spans (e.g. up to 8 metres) and allowing reinforced-concrete floors of minimum overall depth to be built.

35 The different durability requirements of each component can also be taken into account and the steel

coatings can be varied to improve economy.

5 The components of the main decking panels and the
infill panels can be efficiently packaged and transported
to distant assembly sites. This centralises main
production, and can save on transportation costs.

10 The web components of the main decking panels can
be purpose-designed to provide high vertical shear
capacity, thereby allowing the decking panels to be
precambered during manufacture, and to accommodate
regularly-spaced, large unreinforced or reinforced
openings for multiple purposes including the passage of
transverse steel reinforcing bars and prestressing cables
15 (see Fig. 8).

20 Preferably the web components of the main decking
panels include openings punched along the length of the
panel. This is particularly desirable in situations when
it is necessary to entirely fill channel members to form a
solid concrete slab. Two-way acting concrete slabs can
thus be constructed and the resulting structural
efficiencies compared with one-way acting slabs can be
achieved. For this purpose, the lap joints of the main
25 decking panels (and the infill decking panels) should be
shallow, e.g. 20-30 mm.

30 As can be seen in Fig. 9, the openings in the
web components of the main decking panels can be placed
very close to end supports and still perform adequately.
(Computer-controlled punching equipment may be used to
prevent them from being placed too close to the ends of
the real panels.)

35 The web components of the main decking panels
may have deep vertical corrugations (see Fig. 8).
Preferably the corrugations have a pitch of 20-50 mm and a

crest-to-valley height of 3-6 mm. The corrugations make it possible to achieve a high level of vertical shear capacity with the thinnest possible steel sheeting. For easier forming the grade of steel used in the web can be reduced compared with the other components, which also has economic benefits. For economy, the steel can be left uncoated because it is later cast in concrete. This is also a way of reducing glare from sunlight, which can be a safety problem for workers on site working with metal coated decks. The height and spacing of the openings in the webs can be varied along the length of the main decking panels, e.g. to accommodate the passage of transverse prestressing cables which normally vary in height above a slab soffit.

The web components of the main decking panels are preferably roll-formed with a camber in their flat plane. This can be achieved by varying the pitch of the vertical corrugations slightly between the top and bottom of the web.

Separately formed top chord component, web components, and base component, with the web components having the above-described camber, can be assembled on a curved bed to produce a permanent upwards camber in the main decking panel. This allows bending strength rather than flexural stiffness to govern design, which can lead to a significant reduction in the quantity of steel needed to manufacture the main decking panels for any given situation. It also means that a flatter soffit can be produced in the final structure.

To assist with manufacturing, the web components of the main decking panels are preferably assembled at the same angle to the vertical, irrespective of their overall height (see Fig 6). Preferably the angle is in the range of 70-80°.

The distance between the web components of the main decking panels at their connection onto the base component is also preferably kept constant. Therefore, the
5 ribs of the main decking panels vary in width across their tops, becoming narrower as the rib height increases.

The web components of the main decking panels may have outwardly angled flanges or inwardly angled flanges
10 or outwardly/inwardly angled flanges. These options are shown in Fig. 2(b). The options facilitate connection of the web components to the top chord component and to the base component.

15 The openings in the web components of the main decking panel can be partially stamped during manufacture so that they can be selectively knocked out on the building site as required.

20 By way of example, the openings may be knocked out on site over internal walls that run perpendicular to the span of the decking. As a consequence, the decking does not create a void over the walls, which can otherwise be a problem acoustically or for fire rating.

25 It may also be necessary to locally fill the void with concrete over the support in this manner if the support is a steel beam and shear connectors are going to be fitted close to the steel rib of the main decking
30 panel, which would otherwise be weakened by rib punch-through.

The top chord component of the main decking panels is preferably purpose-designed to concentrate a
35 large area of cheaper, uncoated and lower-grade steel near the upper-most extremity of the steel deck. This is a highly efficient way of enhancing the moment capacity and

flexural stiffness of the panels, under conditions of either positive or negative bending.

5 In part the mechanical resistance develops due to the connection formed between the top chord component and the web components.

10 The top chord component may also be embossed, or its edges deformed or punched, to improve the mechanical resistance without interfering with the connection between the components.

15 The top chord component of the main decking panels is preferably designed to develop a sufficiently high level of mechanical resistance with the hardened concrete so that it can act as effective longitudinal tensile or compressive reinforcement in the composite slab.

20 The top chord component of the main decking panel can be designed to be compact, i.e. develop its full potential compressive capacity without failing prematurely by local buckling. This is helped by the component being wide and relatively thick compared with normal steel
25 decking. To be compact it is preferably attached to the web components of the main decking panel at close centres longitudinally along the length of the main decking panel.

30 Preferably, the top chord component of the main decking panels is relatively wide so that it is easy to walk on during construction and provides a wide support to reinforcing bars laid transversely on top.

35 Preferably the top chord component of the main decking panels is relatively thick compared with normal steel decking and therefore is much more robust against accidental damage during handling and on site.

The ends of the top chord component of the main decking panels may be manufactured with mechanical features (e.g. embossments) that enhance the mechanical resistance developed in these regions, thus significantly reducing the length of lapping bars required over support regions in negative bending.

The base component of the main decking panels can be purpose-designed to concentrate a large area of steel and develop a large longitudinal tensile or compressive force near the lower-most extremity of the steel deck. This is a highly efficient way of enhancing the moment capacity and flexural stiffness of the panels, under conditions of either positive or negative bending.

Preferably the base component of the main decking panels includes shallow lapping ribs (preferably 20-30 mm high) and longitudinal stiffeners.

The base component of the main decking panels can be roll-formed from the thinnest possible galvanised high-tensile steel sheeting, e.g. G550, 0.6 mm. The galvanising makes the soffit of the decking durable, which can also be pre-painted for additional corrosion resistance or for appearance and functionality.

Preferably the base component of the main decking panels, acting in conjunction with the web components, is designed to develop a sufficiently high level of mechanical resistance with the hardened concrete so that it can act as effective longitudinal tensile or compressive reinforcement in a composite slab.

The geometry of the ribs of the base component of the main decking panels can be modified slightly to allow the component to be used as an infill decking panel.

The infill decking panels can be purpose-designed to economically cover a gap between adjacent main decking panels.

5

The lap joints of the main and infill decking panels are preferably designed so that the infill decking panels can be installed from the top once the main decking panels are in their final position in the building (see Fig. 5) - this recognises the comparatively limited spanning capability of the infill decking panels compared with the hybrid decking panels.

15 The infill decking panels are also preferably designed to develop a sufficiently high level of mechanical resistance with the hardened concrete so that they can act as effective longitudinal tensile or compressive reinforcement in the composite slab. In order to do this the lap joints may be specially designed to grip concrete and the panels may be embossed or otherwise
20 formed for this purpose.

The infill decking panels may take on a variety of shapes, e.g. flat (possibly including a slight camber) to give a flat soffit, or trapezoidal to create a ribbed one-way composite slab.

25 The infill decking panels may also be fitted with internal voids, such as styrene blocks, to reduce the volume of concrete (Fig 3(b)).

30 For economy, the panels are preferably roll-formed from the thinnest possible galvanised high-tensile steel sheeting, e.g. G550, 0.6 mm. The galvanising makes the soffit of the decking durable, which can also be pre-painted for additional corrosion resistance or for appearance and functionality.

The components of the main decking panels can be assembled together without using welding, and this is an advantage because it allows pre-painted and other types of high-quality sheeting coatings to be used on the exposed soffit of the panels that may otherwise be damaged during a welding operation.

Non-welding connection options include glueing, clinching (without perforating) and conventional mechanical fasteners.

The connection together of the components of the main decking panels is also designed to enhance the mechanical resistance developed by these panels in the hardened concrete. The design of the connection between the components, in particular the frequency of the connections along the length of the panels, can be varied during production to improve economy.

When openings are punched in the web components of the main decking panels, small air breather holes are preferably also simultaneously punched in the tops of the web components to allow air to escape from underneath the top chord components when concrete is poured, thus ensuring that the void formed by the steel rib of the main decking panel is effectively filled with concrete thus allowing a solid slab to be formed.

The corrugated web components of the main decking panels contribute as longitudinal steel in a composite slab, particularly when the steel ribs of these panels are filled with concrete and consequently the web components are sandwiched in the concrete making longitudinal slip very difficult.

The main and infill decking panels can be made to

any length.

Steel diaphragms (Fig. 7) may be fitted near the ends of the main decking panels to strengthen the web components against buckling due to large end reactions.

These diaphragms can also act as plugs to the ends of the channel members of the main decking panels preventing the ingress of concrete when this is required.

10

Either an internal or an external type of steel diaphragm can be fitted at locations where the main decking panels extend over temporary or permanent supports, if it is necessary to strengthen the panels against buckling of the webs due to the large vertical reaction.

15

Intermediate diaphragms or plugs can be fitted at a designated distance in from the ends of the main decking panels, and the openings in the web components can be punched out over this distance only. This can be done to enhance the vertical shear capacity of a composite slab in support regions. It can also be done to form solid concrete flanges of composite beams when composite slabs are shear connected to supporting steel or concrete beams.

25

For a similar purpose, the small open lap joint at the connection between a pair of main decking panels and between a main decking panel and an infill decking panel can be locally squashed together to eliminate the void and therefore not interfere with the performance of any shear connectors placed near these joints if composite beams are formed with steel supporting beams.

30

The infill panels can be holed on site at any location to accommodate vertical building services. The width of the panels may be adjusted as necessary to suit

35

the layout of the services. Purpose-built bridging elements can be used to support any main decking panels that are weakened by being cut to accommodate vertical building services.

5

The main decking panels and infill decking panels can be pre-assembled in a factory or on the ground at the building site into wider panels, with any transverse reinforcing bars required for a given design situation being fitted through openings in the web components of the main decking panels or being positioned to sit on or be attached to the top chord components. These panels can then be lifted into final position, normally by crane. If the supports are not flat, and possibly even curved into an arch, then narrow main and infill decking panels, including the transverse reinforcement, will readily adjust to the shape of the supports.

Longitudinal reinforcing bars or post-tensioning cables can be supported in position so as to be cast in the lower regions of a composite slab between adjacent steel ribs of the main decking panels.

If voids formed by the channel members of the main decking panels are not filled with concrete, then if necessary, alternative materials can be used to improve thermal reflectivity and insulation, e.g. mineral fibre, under fire conditions, and/or sound insulation.

Typically, the main decking panels and infill decking panels are used to construct composite slabs. However, they can readily be used in different combinations and arrangements that suit the construction of non-composite and composite beam and slab arrangements, e.g. see Figs 10 and 11. In these types of applications, the openings in the web components are preferably removed on one side only of the main decking panels.

The use of galvanised decking materials can cause a high level of reflection and glare to the installers. This is an identified safety and OH&S concern on site. The use of dull (non galvanised) materials in particular for the wide top chord component of the main decking panel can greatly enhance safety and worker comfort.

The use of thin material in the pans of the base component of the main and infill decking panels results in transverse deflection between the channel members, with the greater this distance the more pronounced the deflection. The attachment of the web components of the main decking panels to the base component of the panels reduces the effective transverse span and hence deflection and hence minimises this as a design criterion for pan thickness. The void in the infill decking panels component can also act in a similar manner, reducing the transverse deflection and allowing the use of thin materials.

Many modifications may be made to the preferred embodiments of the present invention described above without departing from the spirit and scope of the invention.

Figure 1 - Decks and deck modifications

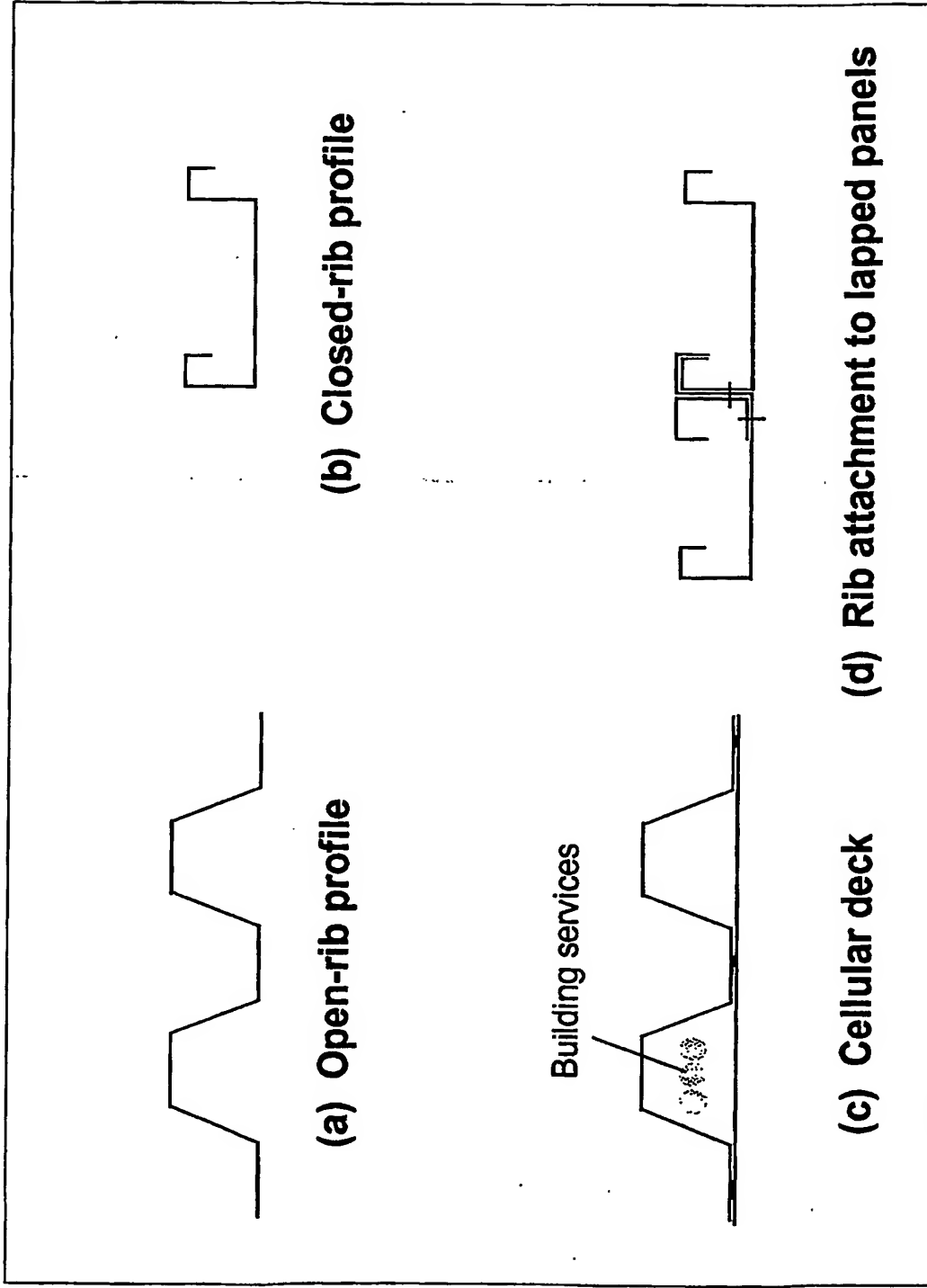


Figure 2 – Hybrid decking panel components and examples of infill decking panels

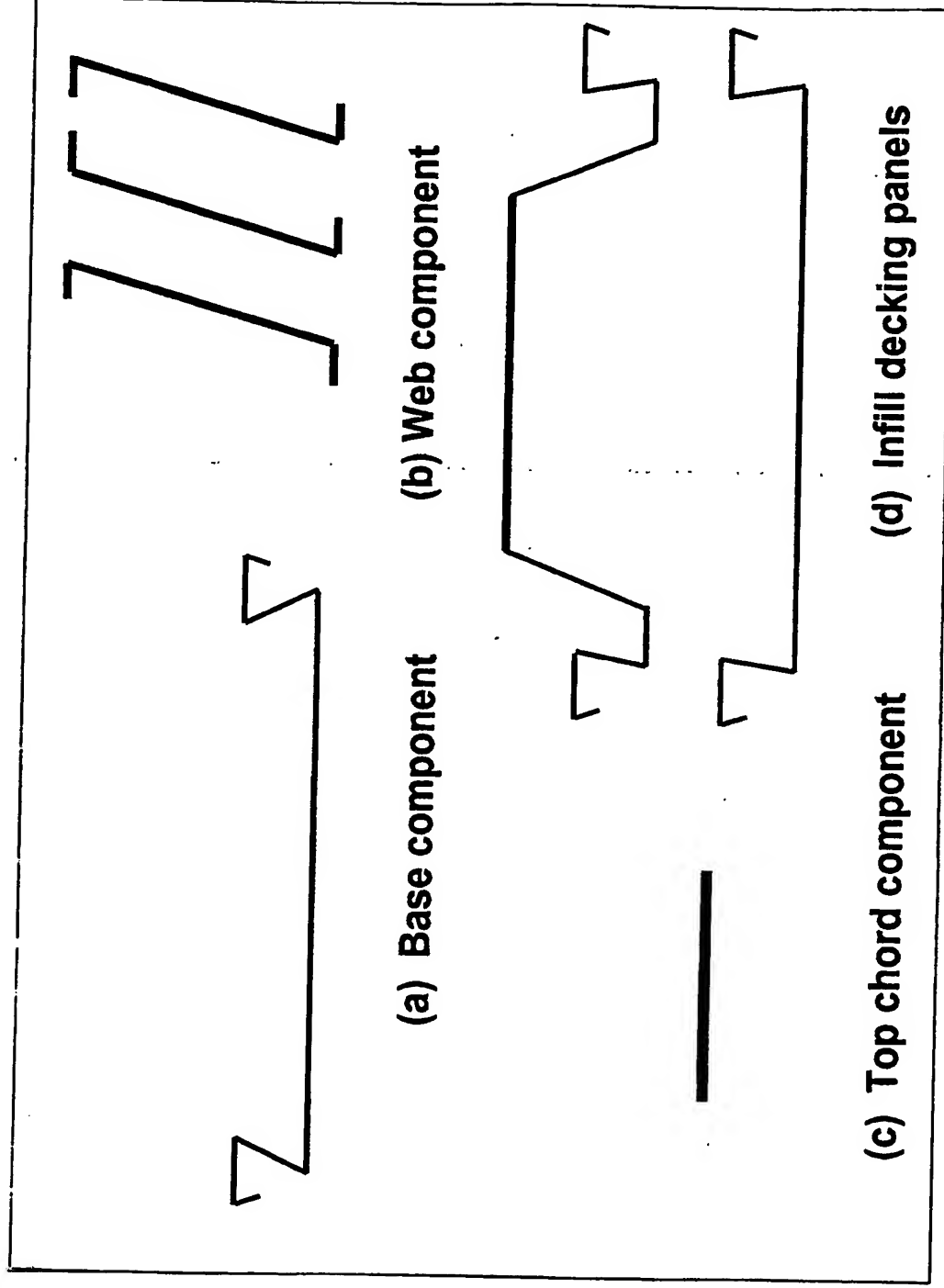
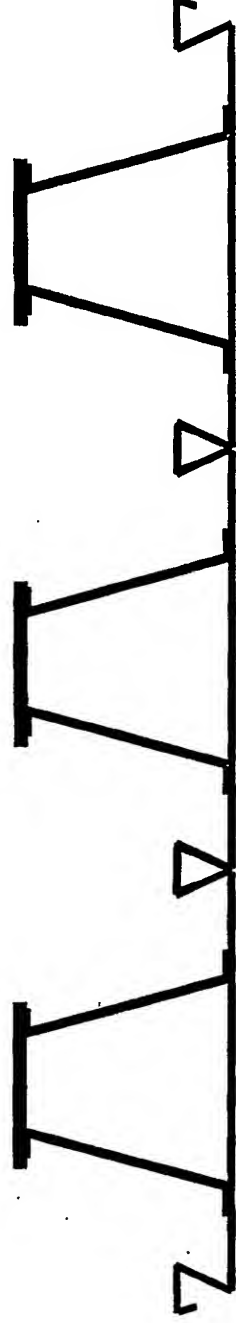
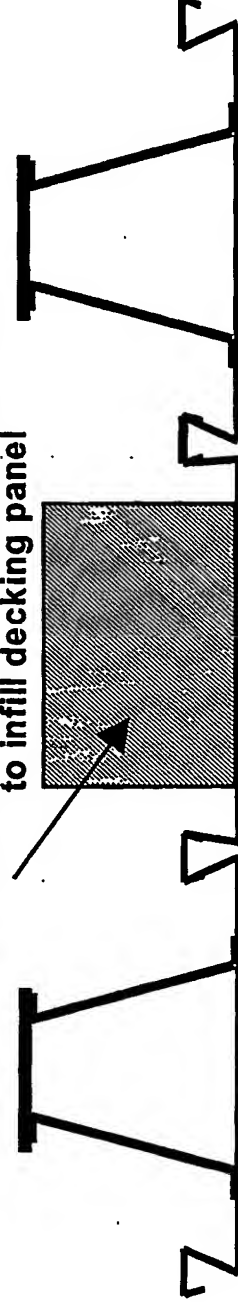


Figure 3 – Examples of hybrid and infill decking panels fitted together



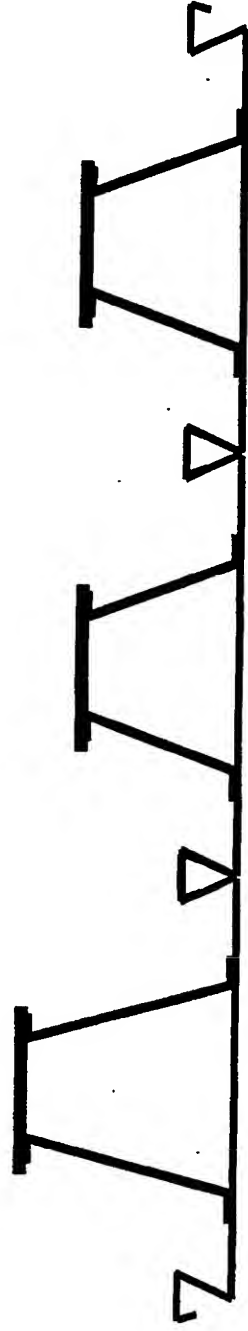
(a) Hybrid decking panels fitted together

Void material, e.g. styrene, can be attached
to infill decking panel

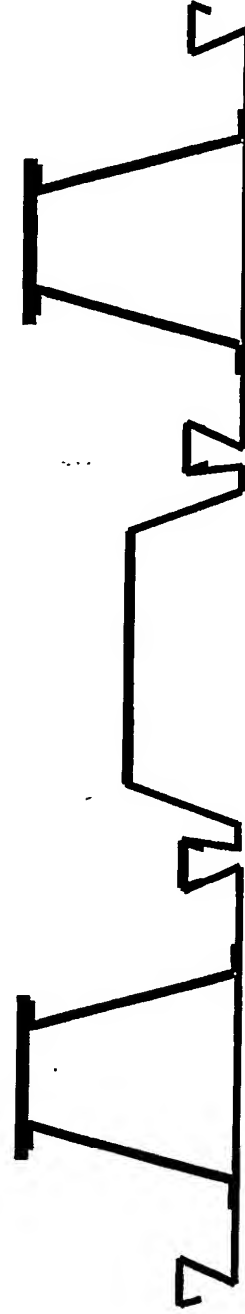


(b) Hybrid decking panels supporting flat infill decking panels to maintain flat soffit appearance

Figure 4 – Further examples of hybrid and infill decking panels fitted together



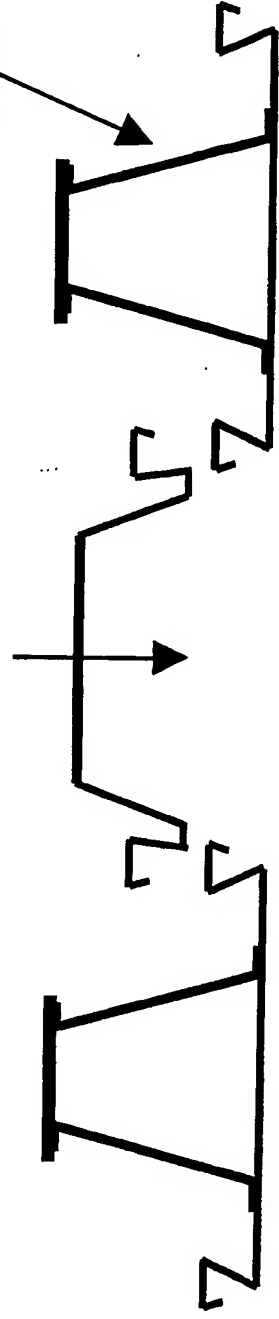
(a) Hybrid decking panels of varying size fitted together



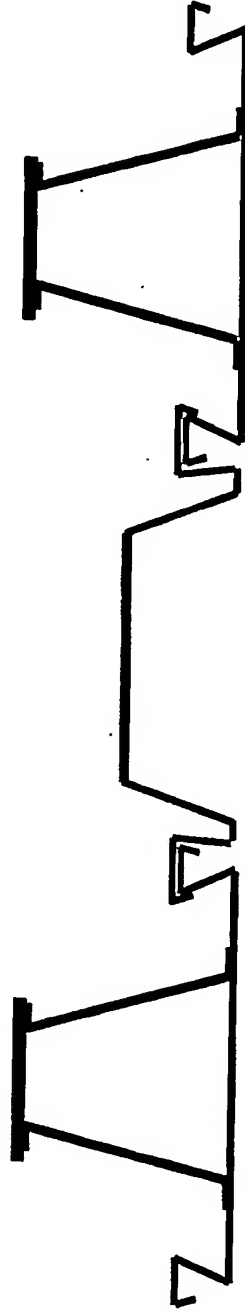
**(b) Hybrid decking panels supporting
trapezoidal infill decking panels**

Figure 5 – Installation of infill decking panels

Hybrid decking panels placed into
position first

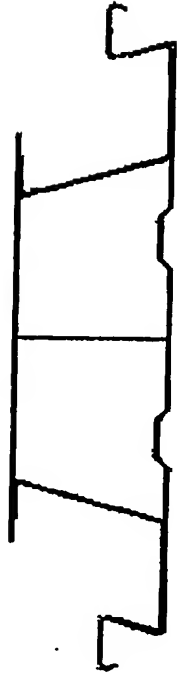


**(a) Infill decking panels fit down over side ribs of
hybrid decking panels**



**(b) Infill decking panel supported by much stiffer and
stronger hybrid decking panels**

Figure 6 – Hybrid and infill decking panel details

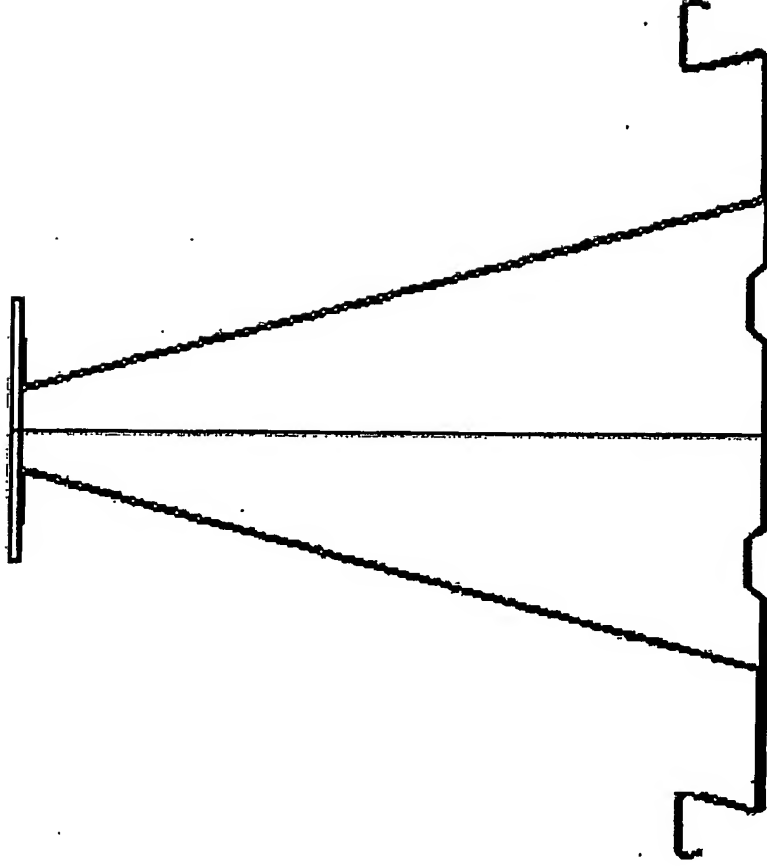


(a) Example of shallow hybrid decking panel



(b) Example of infill decking panel

Figure 6 (continued) – Hybrid and infill decking panel details



(c) Example of deep hybrid decking panel

Figure 7 -- End diaphragm fitted to prevent buckling of webs at support

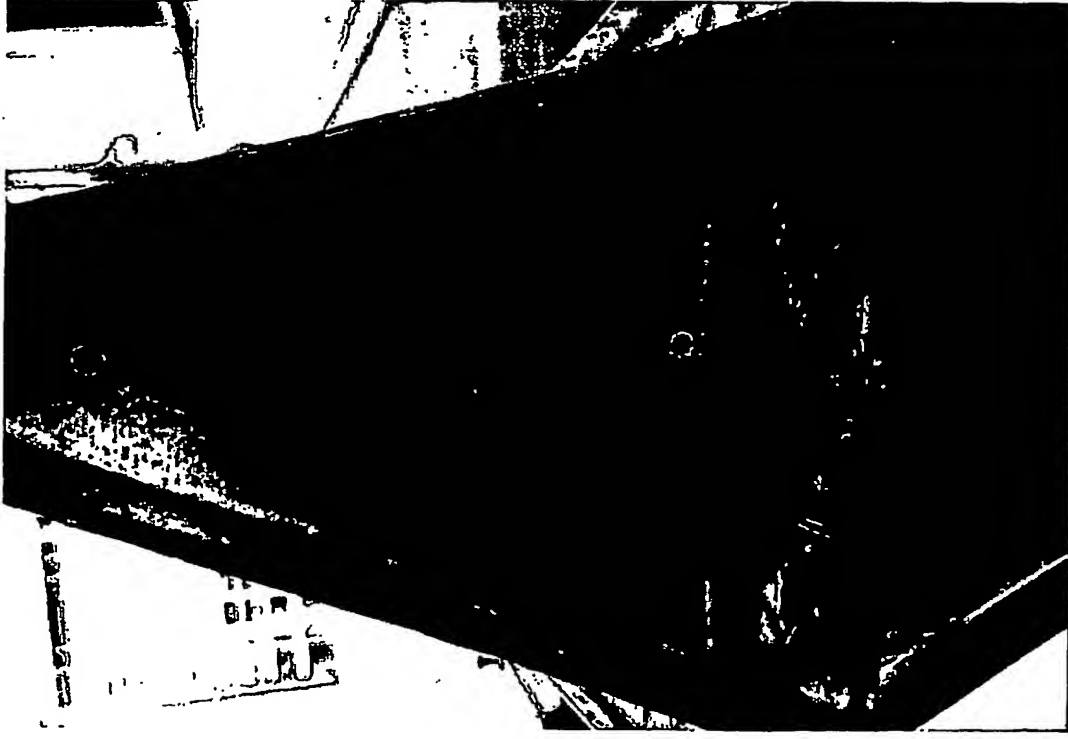


Figure 8 – Regular holing of webs

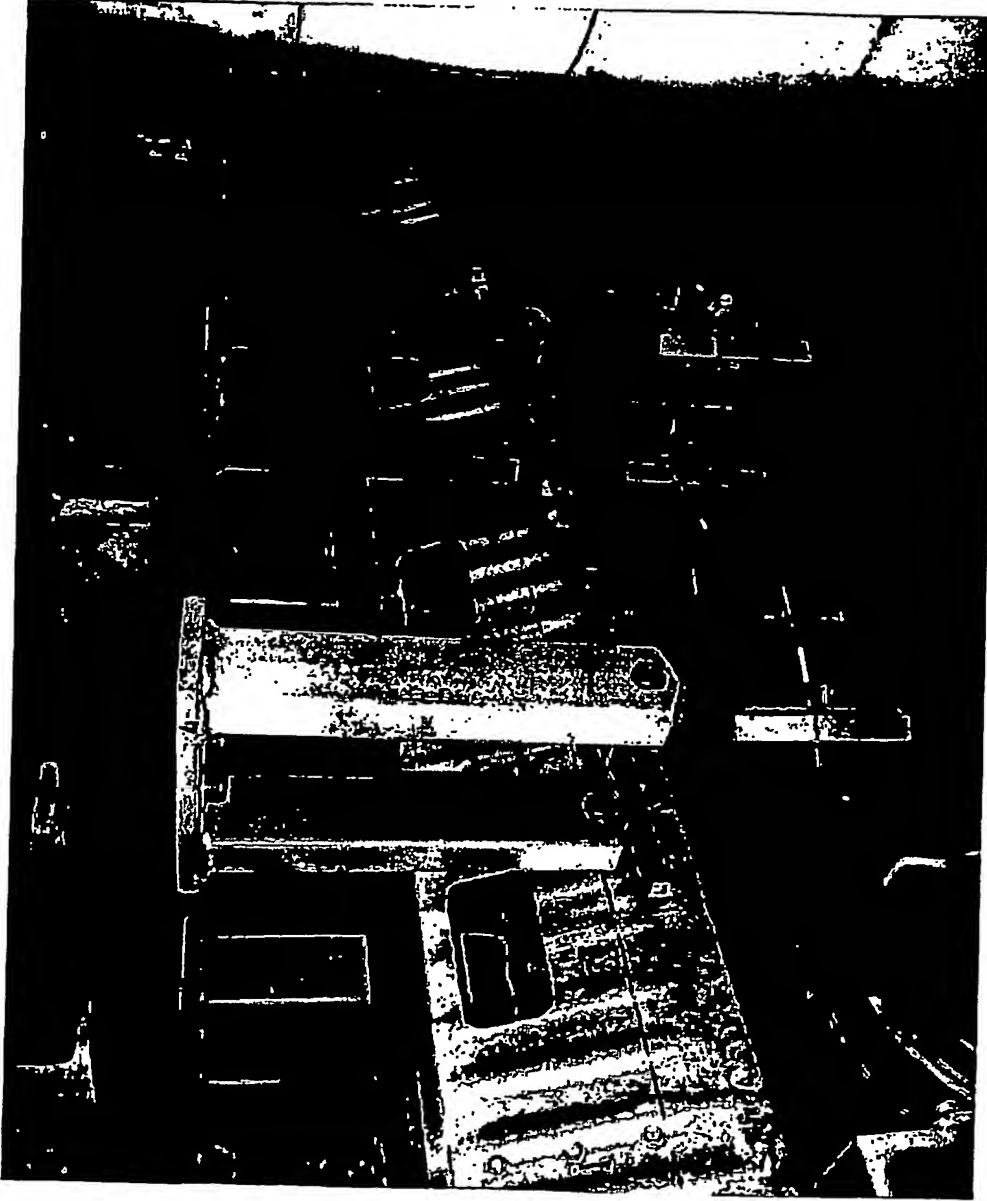


Figure 9 – Shear distortion and buckling of web in region of unreinforced hole at ultimate load

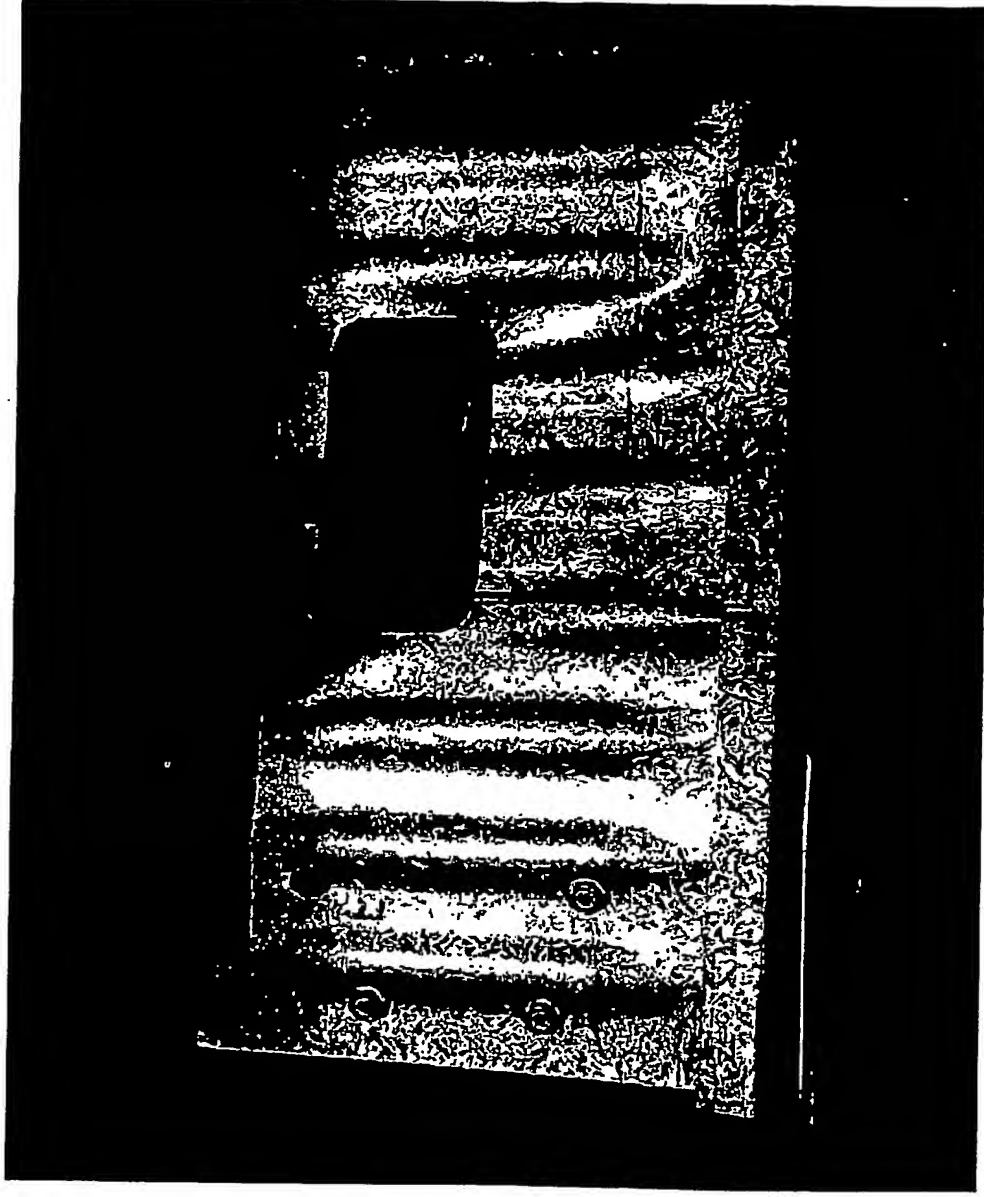
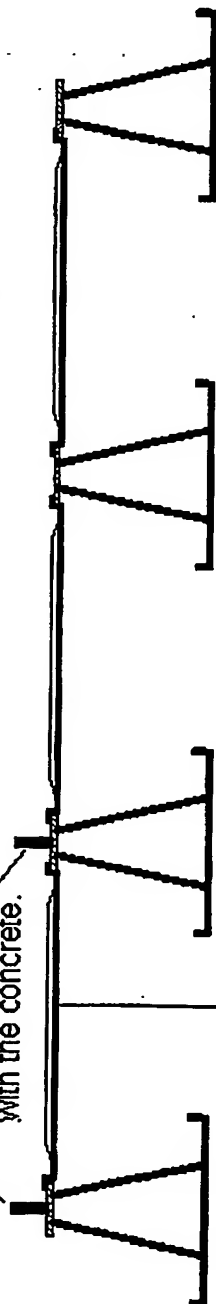


Figure 10 – Alternative arrangements

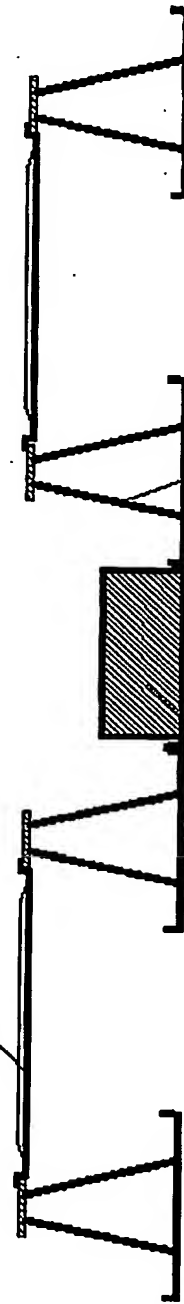
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Ultrafloor equivalents

Conventional or special types of shear connectors can be attached to the top chord of the trusses if composite action between the slab and the trusses is required. Alternatively, the truss top chord could be specially designed to itself develop strong mechanical interlock with the concrete.



Shallow infill panels spanning between truss top chords



Infill panels can also be attached to truss bases as required, to form deep composite beams

Truss could be holed on one side only to allow it to be filled with concrete

Figure 11 – Alternative arrangements

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Bandbeam alternative

